Decapod Crustaceans of the Headwater Streams of Pohnpei, Eastern Caroline Islands, Federated States of Micronesia[1]

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Abstract: Two species of *Macrobrachium* (Palaemonidae) and three atyid shrimp (Atyidae) species were identified among 986 decapod crustaceans collected in headwater streams on Pohnpei, Micronesia, during 1999 and among incidental collections in 2000. None is endemic to the island; all are indigenous or at least not of recent human introduction, and all occur widely in the Indo-West Pacific region and have a diadromous life history pattern. Both *Macrobrachium lar* (Fabricius, 1798) and *M. latimanus* (Von Martens, 1868) are common in Pohnpei rivers, but *M. latimanus* outnumbers *M. lar* especially in the uppermost reaches. *Atyoida pilipes* (Newport, 1847) accounted for 72% of the atyid sample, and it was the only decapod recorded at elevations as high as 604 m; *Caridina weberi* (De Man, 1892) composed 21% of the sample and *C. typus* (H. Milne Edwards, 1837) 6.4%. Ovigerous females were collected throughout the year for three of the five species; the absence of ovigerous *Macrobrachium lar* and *Caridina typus* during August–November was possibly due to small sample sizes. Freshwater shrimps do not currently form an important part of the diet of Pohnpei islanders, but historical accounts suggest that shrimps were utilized more in the past when imported foods and advanced technology for harvesting marine resources were not readily available.

INFORMATION ON THE distribution and abundance of the freshwater biota of Micronesian islands is scanty and widely scattered in the literature. Maciolek and Ford (1987) furnished the first comprehensive inventory of stream macrofauna on Pohnpei. They reported on 44 species, including 10 decapod crustaceans (seven atyids, two palaemonids, and one grapsid crab); their samples were largely from the Nanpil-Kiepw River, and at elevations below about 200 m. No other crustaceans were added to this list during subsequent surveys of the Nanpil and Lehn Mesi Rivers (also at sites below about 200 m) in 1996 (Nelson et al. 1996); there have been no other surveys. This study is the first report on the distribution of freshwater decapods in headwaters (mainly above 200 m) on Pohnpei, and it is based largely on surveys of six rivers during February–November 1999, with ancillary material from March and April 2000. New information is presented on the distribution, relative abundance, morphology, and reproductive condition among two species of *Macrobrachium* (Palaemonidae), *M. lar* (Fabricius, 1798), and *M. latimanus* (Von Martens, 1868), and three atyid shrimps (Atyidae), including *Atyoida pilipes* (Newport, 1847), *Caridina typus* (H. Milne Edwards, 1837), and *C. weberi* (De Man, 1892).

Study Area

Pohnpei is a moderately sized (355 km^2 [MacLean et al. 1986]), ruggedly mountain-

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ous, tropical Pacific island located 766 km north of the equator in the eastern Caroline Islands, Federated States of Micronesia (Figure 1). Maximum elevations in the central highlands are just under 800 m (U.S. Army Corps of Engineers 1986). Densely forested steep ridges and deep valleys give rise to several major watersheds and radiate outward and downward to the coastal lowlands and surrounding mangroves. A discontinuous barrier reef encloses a lagoon up to about 6 km wide. The average annual air temperature is 27°C, and the average monthly temperature does not vary from the annual average by more than 1° (Laird 1982). Mean annual rainfall in Kolonia, the main settlement (on the northern coast), is approximately 485 cm, with estimates for the central highlands ranging to 1015 cm (Merlin et al. 1992).

The vegetation is largely rain forest dominated by dohng (*Campnosperma brevipetiolata*) and sadak (*Elaeocarpus carolinensis*) with patches or stands of the endemic kotop palm (*Clinostigma ponapensis*). Tree ferns (*Cyathea* spp.) are common in the understory, and epiphytic mosses and ferns festoon tree trunks, limbs, and branches. Trustrum (1996) reported a decline in native upland forest from about 42% of vegetation cover in 1975 to about 15% in 1995, attributing it largely to clear-cutting of numerous, small plots for cultivating sakau (kava), *Piper methysticum*. The crushed roots of this plant yield a beverage consumed for its psychoactive properties, and which has long been a part of Pohnpeian tradition and culture. In recent years, however, widespread recreational use has increased the demand, and sakau is the island's most valuable (profitable) cash crop.

The 1994 national census recorded 31,540 people living on Pohnpei, with 6660 of them residing in Kolonia; the others are distributed among smaller settlements mainly along the 87-km-long circumferential road (Office of Planning and Statistics 1996). No roads traverse the island, and the central highlands remain uninhabited. Subsistence farming is widespread near the settlements, and fishing, tourism, and government work contribute to the local economy.

The streams we surveyed averaged about 2–4 m wide and 0.5–1.0 m deep, with some pools below waterfalls reaching depths of 3 m. The streambeds consisted largely of boulders and cobbles with some exposed bedrock and small deposits of gravel. Water temperatures ranged from 23 to 27°C, and elevations at the 33 stations were 146–550 m.

MATERIALS AND METHODS

Specimens were collected using hand-held dip nets at 33 stations on six rivers (Figure 1) during February–November 1999. All collections were made by D.W.B. and D.B.L., with one or two assistants on several occasions. Most of the stations were visited only once, and none more than three times. We collected specimens opportunistically, but proportionately less effort was spent in pursuit of the largest individuals of *Macrobrachium* spp., which were more elusive and difficult to capture. We also curtailed collecting species that were abundant at a locality to focus on those less numerous.

Twenty-six stations (79%) were above 200 m and accounted for 91% (50 hr) of the search effort, loosely defined to include streamside processing of specimens (including fishes), note taking, and time spent walking along the stream bank at each site, in addition to actual collection time. Inasmuch as search effort included several disparate components, we did not calculate a capture rate index for the shrimp. Stations averaged about 25–50 m long; some were confined to single pools and others covered as much as 100–150 m of the streambed. Areas above and below major waterfalls (more than about 8 m high) were treated as separate stations. Fifty-nine additional specimens collected in the Nanpil, Senipehn, and Neh Rivers in March and April 2000 are mentioned in comparisons but were not pooled with the 1999 samples. All specimens were preserved in 10% formalin, washed, transferred to 35% isopropanol, and distributed between the College of Micronesia, the University of Guam, and the Queensland Museum (Australia).

All measurements are in millimeters. For *Macrobrachium* spp., total length was measured as the distance from the tip of the ros-

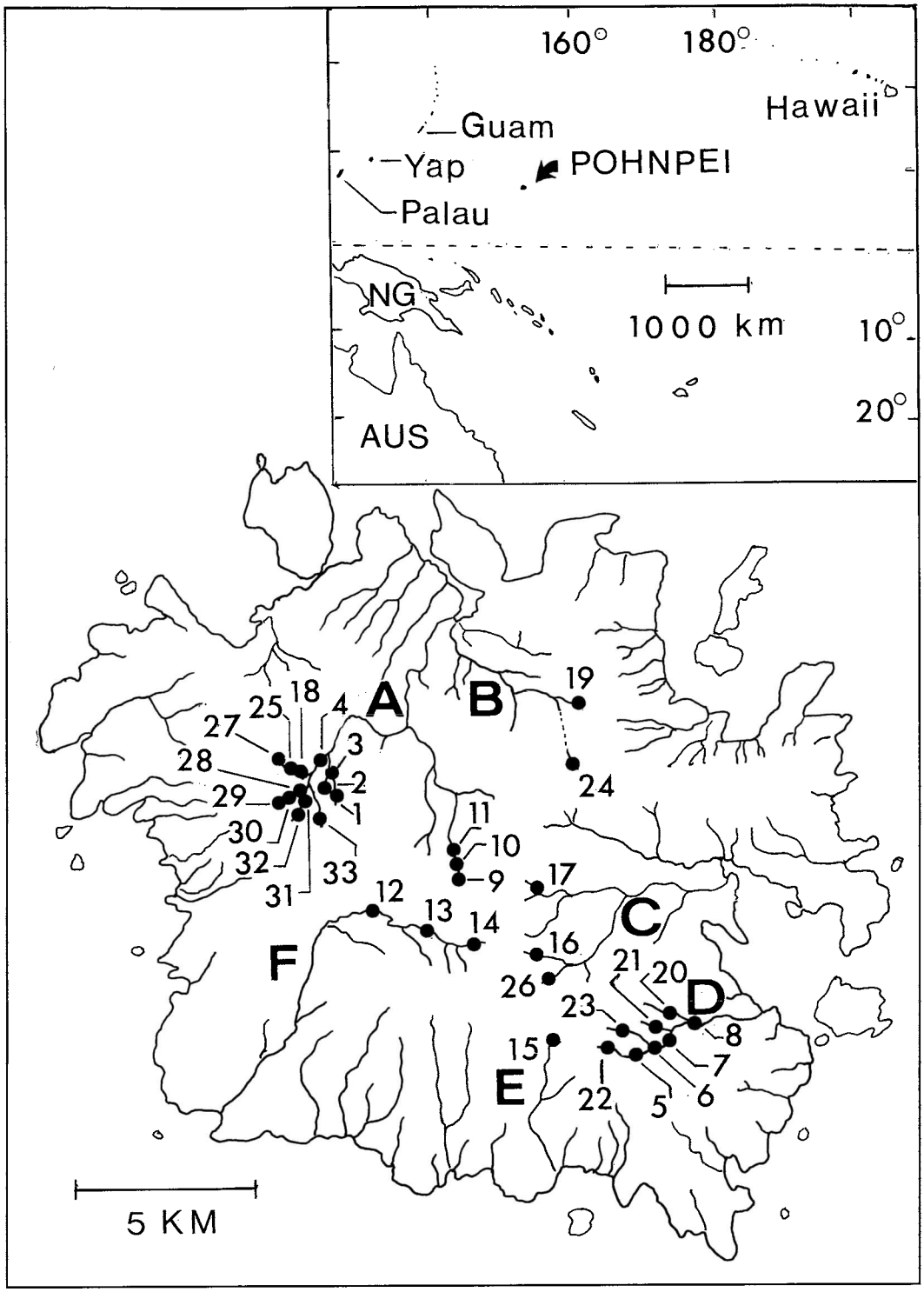

FIGURE 1. Location map for Pohnpei and collecting stations for 1999 headwaters survey. A, Nanpil-Kiepw River; B, Meitik River; C, Senipehn River; D, Mahnd River; E, Neh River; F, Lehn Mesi River; AUS, Australia; NG, New Guinea; broken line, equator.

trum to the tip of the telson (with abdomen extended on a flat surface). Standard postorbital carapace length was measured on all ovigerous females among atyids. Measurements of total length in *M. lar* and *M. latimanus* were submitted to Student's *t*-test to test for sexual dimorphism and interspecific differences in body size.

SPECIES ACCOUNTS

Palaemonidae

Macrobrachium lar and *M. latimanus.* Both species of *Macrobrachium* are widespread in the Indo-West Pacific region from East Africa (in the case of *M. lar*) and India and Sri Lanka (for *M. latimanus*) to as far east as the Marquesas Islands, Polynesia (Chace and Bruce 1993), and *M. lar* has been introduced to Hawai'i (Kubota 1972). Both are common on Pohnpei (Maciolek and Ford 1987, Nelson et al. 1996; this study), but *M. latimanus* is more abundant and widespread in headwater streams than is *M. lar*, accounting for 253 (82%) of the 310 specimens, and reaching farther into the smaller tributaries at higher elevations. In the five stations above 350 m (14, 15, 22, 24, 27), we collected only one *M. lar* in contrast to 65 *M. latimanus.* We collected *M. latimanus* in all six rivers and in 27 (82%) of 33 sampling stations. *Macrobrachium latimanus* may have been present also in four additional stations (7, 9, 11, 17) where examples of *Macrobrachium* unidentified as to species were observed but not collected. Station 1, located on a shallow, narrow tributary of the Nanpil-Kiepw River, is the only site where we did not observe *Macrobrachium.* We collected *M. lar* at 14 (42%) of the stations, but none in the Meitik, Senipehn, and Neh Rivers (all 48 specimens were *M. latimanus*), although it may occur in one or more of those drainages, especially at lower elevations.

Macrobrachium lar averaged larger than *M. latimanus* both in males ($t = 2.75$, $df = 104$, $P < 0.01$) and in ovigerous females ($t = 9.70$, $df = 52$, $P < 0.01$) (Table 1). Males of *M. latimanus* were significantly larger than females ($t = 5.90$, $df = 236$, $P < 0.01$), but sexual dimorphism in total length was less evident in *M. lar* ($t = 0.17$, $df = 53$, $P > 0.05$), although 10 of the 30 males (33%) were larger than the largest among 25 females. Immature specimens less than 30.0 mm in total length were scarce in all our samples; all 12 were males, and all but one were *M. latimanus.*

TABLE 1

Total Length Measurements (Range, *n*, Mean ± SD) for *Macrobrachium* spp. Collected in Headwater Streams on Pohnpei during February–November 1999

Size Class and Sex	*M. lar*	*M. latimanus*
>30.0 mm		
Males	35.0–141.5 (30) 82.9 ± 33.2	30.9–105.0 (162) 65.5 ± 15.0
All females	49.9–108.7 (25) 81.7 ± 16.8	31.2–92.1 (76) 54.4 ± 12.6
Ovigerous females	73.2–106.2 (11) 89.3 ± 9.0	34.3–92.1 (43) 56.4 ± 12.0
<30.0 mm		
Males	29.9 (1)	21.3–29.9 (11) 25.3 ± 3.1
Females	(0)	(0)

The sample of ovigerous females was too small to assess seasonality in reproduction confidently. Nevertheless, the scanty evidence indicates that *M. latimanus* breeds throughout the year, because 14 (74%) of 19 females collected during February–May were ovigerous, as were 29 (50%) of 58 collected during August–November. In the case of *M. lar*, 11 (55%) of 20 females collected during February–May were ovigerous, but none among the six collected during August–November, although this was possibly an artifact of small sample size.

Atyidae

Atyoida pilipes. This species is widespread in the Indo-West Pacific region and ranges from the Sunda Islands, Indonesia, to as far east as the Gambier Islands, Polynesia (Chace 1997). It was abundant in Pohnpei headwaters, accounting for 489 (72.3%) of 676 atyids collected in 1999 (Table 2). We collected it at 24 (72.7%) of the 33 stations and in five of six rivers; its absence from the Neh

TABLE 2

Distribution of Atyid Shrimps Collected in Pohnpei Headwater Streams during February–November 1999, with Percentages across Species in Parentheses

River System	*Atyoida pilipes*	*Caridina typus*	*Caridina weberi*
Nanpil Kiepw	195 (83.3)	8 (3.4)	31 (13.3)
Meitik	100 (100)	0	0
Senipehn	105 (87.5)	0	15 (12.5)
Mahnd	39 (38.2)	2 (2.0)	61 (59.8)
Neh	0	33 (97.0)	1 (3.0)
Lehn Mesi	50 (58.1)	0	36 (41.9)

TABLE 3

Relative Abundance[a] of Ovigerous Females of Atyid Shrimps Collected in Pohnpei Headwater Streams during February–November 1999[b]

Month	*Atyoida pilipes*	*Caridina typus*	*Caridina weberi*
February	1/17 (5.9)	0/1	7/49 (8.9)
March	1/38 (2.6)	2/9 (22.2)	6/30 (20.0)
April	61/79 (77.2)	0/24	4/15 (26.7)
May	50/134 (37.3)	0/2	8/32 (25.0)
August	13/80 (16.3)		1/9 (11.1)
September	17/51 (33.3)		5/9 (55.6)
October	10/45 (22.2)	0/7	
November	14/45 (31.1)		

[a] The number of ovigerous females divided by the total number of specimens collected (by species), with percentages in parentheses.

[b] Excluding June and July when no collections were made.

TABLE 4

Carapace Length in Ovigerous Females of Atyid Shrimps Collected in Pohnpei Headwater Streams during February–November 1999

Species	*n*	Carapace Length (mm)
Atyoida pilipes	167	5.6–8.3
Caridina typus	2	3.9–4.3[a]
Caridina weberi	31	4.3–5.5
Caridina sp.	1	3.5

[a] Another collected in the Nanpil River (upper extension of station 29) at 336–366 m on 30 March 2000 measured 5.9 mm.

River (with only one station) may be artifactual. It is especially abundant in cascades and waterfalls, clinging to rocks behind the main flow of the current. At some localities, it was possible to collect 5–10 at a time simply by passing a cupped hand along the under and lateral surfaces of the rocks. Ovigerous females were collected throughout the year, with proportionally more in April (Table 3); however, this finding is based almost entirely on one sample from station 16 on the Senipehn River, where 61 of 73 (83.6%) were ovigerous. In Palau, Bright (1979) found ovigerous females relatively most numerous in August. Bascom (1946) alluded to an annual upstream migration of atyids in Pohnpei rivers around April that probably included this species.

Caridina typus. This species has a broad distribution in the Indo-West Pacific region from eastern Africa to Polynesia (Chace 1997). It was the least common of the three atyids in Pohnpei headwater streams, accounting for only 43 (6.4%) of the specimens collected, with 33 of them (97%) being from station 15 on the Neh River (Table 2). It was unrecorded in the lower reaches by Nelson et al. (1996) and collected there only in small numbers by Maciolek and Ford (1987). Small to medium-sized adults from Pohnpei lack teeth on the ventral margin of the rostrum, whereas in other parts of its range the adults usually are armed with one to six teeth (Chace 1997). The two ovigerous females (both from station 15) were among the smallest of any ovigerous specimens we collected in 1999 (Table 3), but another collected in the Nanpil River in March 2000 exceeds the upper range limit for carapace length in our samples of *C. weberi* (Table 4).

Caridina weberi. This shrimp is another wide-ranging Indo-West Pacific species. It has been recorded from India to as far east as the Marquesas Islands, Polynesia (Hung et al. 1993, Chace 1997). It was fairly common in Pohnpei headwaters, accounting for 144 (21.3%) of the atyids collected, and at 14 (42.4%) of the 33 stations. It was common also in the surveys at lower elevations (Maciolek and Ford 1987, Nelson et al. 1996). We found ovigerous females during each month specimens of *C. weberi* were col-

lected (February–May, August, and September), but this species was not among the 97 atyids collected during October and November 1999.

The position of the antennal spine relative to the inferior orbit is highly variable in Pohnpei specimens. Throughout much of its geographic range, *C. weberi* usually has the antennal spine fused with the inferior orbit (Choy 1991, Chace 1997), but in most of the Pohnpei specimens the spine is located below and distinct from the orbit. In addition, some of the Pohnpei specimens exceed the upper range limit of 20 dorsal rostral teeth reported by Chace (1997) for the species.

DISCUSSION

Of the 10 species of decapods recorded in Pohnpei rivers (see Maciolek and Ford 1987), five were among the 986 specimens collected in headwater streams in 1999. Previously recorded species not encountered include a grapsid crab (*Parasesarma* sp.) and the atyids *Atyopsis spinipes*, *Caridina brachydactyla*, *C. longirostris*, and *C. vitiensis*. One *Caridina* with an apparently deformed rostrum we collected in the Nanpil River in March 2000 was unidentified as to species. The highest elevation that specimens were found in this study was 604 m on the Senipehn River, above station 26, where we collected seven *Atyoida pilipes* on 19 April 2000. None of the 10 species is endemic to Pohnpei, and all five from the uplands are widely distributed among tropical western Pacific islands. Such broad distributions are in marked contrast to the high level of endemism among gobiid fishes from the same localities; at least three of the five gobies (60%) are endemic to the island (Buden et al. in press). The shrimps and gobies we collected all share a diadromous lifestyle, including marine dispersal as larvae and in some cases juveniles (Maciolek and Ford 1987, Parenti and Maciolek 1993, Nelson et al. 1996, 1997). We are uncertain as to the selection pressures contributing to the disparity in levels of endemism in these two prominent components of the stream macrofauna.

Caridina typus was scarce in our samples (6.4% of the atyids collected in 1999), but the other four decapod species were encountered regularly and at no fewer than 14 of 33 stations. *Caridina typus* was poorly represented also at lower elevations on Pohnpei (Maciolek and Ford 1987, Nelson et al. 1996), and it was uncommon in the upper reaches of rivers on Palau (Bright 1979). However, it was common "in first order streamlets [on Palau] which originated within 1–2 km of the sea" (Bright 1989:34), and its abundance on Yap (67% of the specimens collected in September 1988) may be due to a preponderance of such habitat (Bright 1989).

Atyoida pilipes was found mainly in cascades and waterfalls unlike the other atyids, which were found mainly in pools, runs, and riffles. Its habitat preference, together with chelae adapted for both filter feeding and sweeping (Chace 1983) as opposed to substrate feeding, and its large body size among atyids suggest that *A. pilipes* occupies a niche markedly distinct from that of any of the four other decapod species. *Caridina typus* and *C. weberi* overlap broadly in body size, have morphologically similar feeding appendages, and probably very similar feeding ecologies. Competitive exclusion may be a factor contributing to the pattern of distribution of these two species on Pohnpei, where (small sample sizes notwithstanding) 95% of the *C. typus* were collected in localities that accounted for only 22% of the *C. weberi*. In addition, *C. weberi* was not encountered in two of the five stations where *C. typus* was collected. In another possible case of exclusion involving *C. typus*, Bright (1989) reported that nearly 80% of *C. gracilirostris* collected on Yap were in areas where *C. typus* was absent.

How the two much larger palaemonids partition resources is uncertain. *Macrobrachium lar* is "an omnivore with carnivorous tendencies" (Maciolek 1972:554), and *M. latimanus* almost certainly feeds similarly. But the two species differ in body size and in the length and robustness of their chelae, and *M. latimanus* greatly outnumbers *M. lar* in the higher elevations. *Macrobrachium latimanus* also is common in the upper reaches of streams in French Polynesia (Marquet 1991,

Fossati and Danigo 1995), but apparently is limited to the lower reaches of streams in Palau (Bright 1979).

Large body size, palatability, and widespread distribution are among the characteristics that make *Macrobrachium lar* a potential candidate for aquaculture throughout the tropical Pacific (Maciolek 1972). Traditional small-scale fisheries for both *M. lar* and *M. latimanus* have long existed among Pacific islands (Holthuis 1980). Pohnpeians harvest *Macrobrachium* spp. from time to time, and atyids occasionally also are eaten (P. Gallen, pers. comm.). However, freshwater shrimps are not an important part of Pohnpeian diet. One of the reasons is that river shrimps are considered to be somewhat plebeian by many islanders, more suited as survival fare and for children to catch and eat opportunistically (P. Gallen, pers. comm.). Some residents indicated that upland populations are inconveniently located and those in the lower reaches may be contaminated by pollution. A. Edward (pers. comm.) received unconfirmed reports that some islanders developed a skin rash after eating freshwater shrimp.

Although largely ignored now, river shrimps were utilized more in the past when imported foods (upon which the people now largely depend) and advanced technology for harvesting marine resources were not available. Bascom (1946:251) stated that "freshwater shrimp [likathapw or likosiang = *Macrobrachium* spp.?] ... is caught with dip nets in the mountain streams by women.... A similar shrimp (likashapw en seth) and a tiny shrimp (lur) described as the size of a grain of rice are caught in the salt water. The latter swims into the lagoon and up the rivers by the millions each year about April, when men, women and children stand in the shallow water along the river banks and scoop them up with baskets, bowls, or whatever is handy." Many islanders we queried were familiar with the name "luhr," applying it to *Atyoida pilipes* (and possibly also *Caridina* spp.), but we were unable to confirm annual upstream migrations, nor were we able to assign the name "likathapw en seth" (literally "shrimp of the ocean") to any one species.

Although freshwater crustaceans are not favored as food by Pohnpeians, they doubtless contribute to the economy of the streams, recycling nutrients and providing food for the other inhabitants. Decapods are often the dominant invertebrates in tropical island streams (Bright 1982). Nelson et al. (1996) recorded an average of 1.8 *Macrobrachium* spp. per square meter in the Lehn Mesi and Nanpil-Kiepw Rivers, and Bright (1979) recorded juvenile *Atyoida pilipes* in densities of at least 350/m^2 in downstream sites on Palau and went on to state that decapods contributed up to 85% of the benthic biomass in pools and cascades. Our qualitative observations indicate that decapods are the most numerous and ubiquitous of the stream macrofauna on Pohnpei.

The decapod crustaceans in Pohnpei rivers currently appear unthreatened and unendangered. The chief predator of shrimp in the upper reaches of the rivers probably is an eel, *Anguilla marmorata*, which reaches lengths of about 2 m and is common throughout. The resident islanders harvest shrimp only occasionally and pose no direct threat. However, progressive encroachment of agriculture into the highlands, including the clearing of 1- to 2-ha plots on montane slopes adjacent to headwater streams, is likely to alter stream ecology (light, temperature, turbidity, volume fluctuations, etc.) in ways that may impact negatively on many stream species.

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